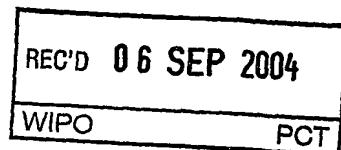




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## **Patent : Cognitive Process Monitor**

**A blink measurement device and method to quantify and characterize cognitive activity in the brain**

**Inventor: Peter G Burton**

### **Device and Measurement System for Tracking Cognitive Brain Activity**

A device is described which comprises:

1. an electromagnetic sensor capable of detecting electro-ocular activity associated with eye blinks, at least one but preferably two such devices attached to the face of a subject
2. connectors from one or both sensors to a transmission unit
3. receiver for blink data information, and
4. storage and presentation device for blink sequence data.

This device must be capable of continuously tracking the profile of individual blinks and operate at at least 40 Hz, preferably 256 Hz, and also precisely locate the time of incidence to within 50 ms, preferably 20 ms, of each blink within a given experimental time interval,  $T$ . Code in the receiver collects blink data during each experimental setting and translates it into a sequence of ordered pairs of data  $\{t, \tau\}$  characterising the time since the outset or the most recent blink in the experimental interval,  $t$ , and the half-width of the blink itself,  $\tau$ .

A method is described which uses the blink data collected as pairs from the said device and comprises:

1. the two dimensional graphical representation of primary blink data into representative maps of blink sequences
2. the analysis of these maps into status quadrant and blink sequence structure and parsed cluster codons, and
3. the comparison of the performance maps of individuals experiencing a common setting, to determine the efficiency of cognition amongst individuals in the setting.

This data may be correlated with age, gender, educational attainment for normal subjects, so as to form a normative database for each of a series of tests against which to assess abnormal cognitive performance which may arise from genetic influence, from development level, from differing degrees of expertise in a domain, from disease states, from psychological influences or pharmaceutical use or food ingestion.

The inventive step is that the blink activity to be useful in discriminating individual performance must be measured jointly by two separate parameters of blinking, the first the interval between two blinks (the interblink interval,  $t$ ) and the second is the depth of each individual blink (as measured by its half-width at half height,  $\tau$  or a more approximate measure such as the percentage closure of the blink,  $\text{perclos}$ ).

Merely counting blinks of any kind to determine an average blink rate for the experiment washes out diagnostic information contained in how the interblink interval  $t$  relates to its nearest neighbours, which is strongly influenced by cognitive activity. Blinks may be counted from the EOG eyeblink trace of typical EEG (electroencephalography), but conventionally these have been regarded as artefacts which should be removed since they distort the signal in frequencies considered diagnostic of forebrain activity. In this invention the blink artefact is turned into the focus of target information content, instead of the continuous

cyclical data characteristic of the oscillating power of the conventional EEG frequency bands. In this invention, information is also collected in the time domain, not the frequency domain (its inverse) characteristic of EEG. Direct measurement via the EOG voltage of the blink time parameters also simplifies data collection apparatus so that measurements may be taken in a much wider group of settings that is possible for EEG measurements.

Merely measuring  $\tau$  the blink depth parameter (or else perclos) only provides information related to fatigue or alertness, the activation of the experimental subject.

With two dimensions of the data set collected for each individual, the correlation between the two parameters may be examined for each pair, and higher order correlation data examined for nearest neighbour pairs, triples etc. In this invention, individual pairs, neighbour pairs and neighbouring triples are contributors to valuable diagnosis and discrimination of cognitive performance.

As we show below, these two parameters also allow the data collected to be displayed in a manner which is highly informative of the actual timecourse of cognitive processing in relation to specific aspects of the experimental task or tests, including the period in which instructions are being given to the subject. This allows serial pair data to be subdivided into batches which pertain to certain kinds of cognitive tasks within an experiment.

One utility claimed of these measurements is to quantify characteristics of personal cognitive processing structure and so compare learning performance of individuals within certain experimental settings relevant to tasks anticipated in work environments. Learning performance comparisons then enables selection of individuals most suited to the proposed task structure, and furthermore for each individual, allows the objective identification of factors which are detractors from optimal performance of an individual.

This system is proposed for use in critical performance tasks, in military, safety, industrial process and financial market settings, as well as educational settings. In particular the training rate of each individual is useful as a predictor of meeting sustained performance objectives by that individual. It will be understood that such device measurements and analysis will also be of value in more general educational settings to objectively assess the learning competence of an individual against his/her peers with prescribed subject matter.

Critical to this system of innovation, measurement device and analytical framework is the means of excluding as much extraneous and irrelevant data from the cognitive measurement system as possible, in particular short-term perceptual processing data, or longer term stative or homeostatic data, in order to focus only upon psychometric data of most direct relevance to the actual timescales of cognitive processing in the brain.

The device and measurement system thus provides a systematic basis for characterising normal and abnormal cognitive performance metrics, which are proposed to complement the symptomology of any particular neurological and psychiatric illness and disorder as currently described in DSM IV (and sequelae), so providing an objective basis for the measurement of the impact of treatments (including drug treatments) of that illness or disorder. Thus the device and measurement system will have major use in tracking the efficacy of drug and other treatments for psychiatric illness, including but not limited to ADHD, depression, schizophrenia, OCD, autism and Parkinson's Disease. The various roles of the monoaminergic neurotransmitters dopamine, noradrenaline and serotonin within cognitive processing show relation to certain aspects of blink activity, which thus provides the psychophysiological link between abnormal blinks and psychiatric and psycho-disorders.

Blinks are phasically correlated with general monoaminergic neurotransmitter activity in the brain, so catecholaminergic disorders or drugs are expected to be a major application of this invention.

### **Precis: Tracking and Clustering of Blink Measurements**

Fatigue and Stress are two conditions or states which are widely considered to compromise cognitive performance relative to the underlying level of ability when alert and relaxed, respectively. The underlying level of cognitive ability of an individual is itself compromised either transiently or more systematically as a result of trauma (such as Post-Traumatic Stress Disorder, PTSD) or disease (such as dementia associated with Alzheimer's Disease, AD), respectively. Defining objective criteria medically relating to cognitive performance such as in depression has been hindered by the subjective nature of self-reports which are often the sole direct evidence for (a) the particular states of an individual from time to time, (b) the longitudinal evolution of state(s) in an individual over time, and (c) the comparison of an individual with supposed peers. Traditionally the scoring of tests has been the basis of assessment of cognitive ability, but these reflect not only intrinsic cognitive ability but also prior cultural, economic and educational circumstances of the individual, factors which are themselves predictive of future performance so confounding the test results in respect of intrinsic ability at a given time.

In order to assess intrinsic cognitive ability, psycho-medical science would like access to indicators of underlying brain processing capability. Unfortunately, no theory is available to guide the development of such indicators. Empirical brain activity measures (EEG analysis) and structural brain imaging (PET, fMRI) straddle the time domain of likely strings of coherent brain activity (the former being too short with measurements focussed upon the *second* following stimulus; the latter subject to repetitive statistical measurement protocols of simple first order tasks, but with at least tens of seconds, possibly *tens of minutes*, of data collection time). Cognitive activity tends to occur as coherent forms of processing over burst periods of seconds to tens of seconds, out of 'range' of EEG (which is too short term, focussing on Event-related Potentials, ERP up to 1000ms), out of match with the multiple repeat statistical sampling rates required for fMRI, and too fast for PET.

The present invention provides a means of data collection in relation to normal cognitive tasks in a natural setting, being designed to objectively characterise brain activity over coherent strings (or larger chains of these) of focussed cognitive activity. This provides for a data-collection paradigm which is capable of discriminating the cognitive performance of an individual across internal states and external task settings, longitudinally across time for those same states or settings, and between individuals.

The measurement technique is non-invasive, and claims to provide an objective quantification of brain activity directly related to higher brain function. The innovation disclosed here relates to a passive tracking and objective methods for characterising brain activity particularly in relation to higher cognitive activity relative to and as distinct from other perceptual or physiological maintenance activity. The measurement process for this method analyses **endogenous eyeblink activity** (in particular, in the preferred instance of this device, through EOG activity) into certain blink types and characteristic interblink intervals, which unit structure provides the analytical basis for tracking and clustering of blink activity into patterns representative of certain distinct kinds of brain processing activity.

The present invention characterises blink types and blink interval characteristics in such a way as to accurately reflect underlying brain processing structure. This characterisation of underlying brain processing structure provides a means of comparing individual performance

under standardised test situations, so providing the basis for data collection and comparative analysis of individual brain processing performance.

### **Claims**

#### **General Claims**

1. Blink metrics may be found to correlate with underlying brain states of alertness, attention and cognitive activity, so discriminating different phases of conscious activity.
2. Blink types reflect the incidence of operation of distinct brain control mechanisms which influence cognitive processing.
3. The local temporal structure of blink sequences, when analysed in terms of both blink types and sequences of interblink intervals, characterises different kinds of computational activity in the brain.
4. Brain computation conforms to repeated patterns of stereotyped activity which can be broken down into basic templates.
5. Brain computational templates encompass (short) coherent passages of brain computation.
6. The fundamental templates are four in number and these represent four distinct patterns of co-activation of localised brain activity.
7. Brain template computation is characterised by patterns of interrelated interval (i.e. attention or concentration) and brain control incidence activity (i.e. blinks).

#### **Context-related Claims**

1. In a standardised setting of cognitive testing, individual differences in blink pair metrics can be used to non-invasively diagnose the incidence of types of brain activity.
2. The incidence of different types of brain activity within a certain context can be used to show changes in brain processing over time for an individual, therefore responding to brain trauma or reflecting progress in a disease state.
3. When standardised cognitive testing tasks such as computer controlled testing of different aspects of cognition are undertaken by individuals, the scoring of the answers or responses to these tests reflect individual differences in cognitive ability. These differences arise from different underlying brain processing competences, so blink pair metric analysis show changes reflecting these differing task environments.
4. Individual differences on a single task, and group differences across tasks, sample different kinds of brain processing, leading to individual differences in blink patterns on a single task, and group differences in blink patterns across tasks.

#### **Local metrics of blinks Claims**

The determination of average blink rates over long periods (more than 2 minutes) wash out most diagnostically discriminating activity related to underlying brain processing, which tends to occur in shorter bursts of ten seconds or less. For such smaller assessment periods:

1. Blink depth and duration is a critical blink parameter. Both the 'Perclos' measure of depth of eyelid closure, and the duration measure of each blink (the half-width in time of the blink at half its depth,  $\tau$ ) are useful measures, the former especially for fatigue studies, the latter especially for cognition studies, where miniblinks are more frequent.
2. The interblink interval,  $t$ , and its pairwise longitudinal autocorrelation (first-order, between nearest neighbours of intervals) and higher order local autocorrelation clustering of inter-blink intervals are also critical blink metrics.

3. Cross correlation metrics between interval and blink duration pairs however provide maximal diagnostic discrimination.

Diagnostic strength blink pair metric of underlying brain activity can be simply illustrated by mapping local coherent strings of activity in the  $\{\tau, t\}$  plane.

### Section 1. Introduction to Blinks as a cognitive measure

Realtime brain activity which characterises coherent cognitive activity tends to occur in bursts interleaved with survival tasks. Provided that measurement conditions control for such latter tasks, cognitively rich aspects of brain processing can be the basis of self-reporting, but self-reports (a) are entirely subjective, and (b) provide no objective basis of comparison across individuals. Scoring of tests provides the conventional means for discriminating performance, but such tests are invariably culturally and educationally loaded, and will reflect the contents of past experience and the accessibility of its memory rather than current general competence in brain processing. Ideally we seek objective measures of brain processing capability independent of prior cultural or education attainment, if we are to objectively track changes in that competence for individuals who are part of a general population, diverse in age, genetic background and educational attainment.

The present invention provides a means of objectively assessing the quality of cognitive activity in a controlled setting, thereby providing a means of comparison of an individual against a standardised control group (which may be age or otherwise, for example, educationally matched) relevant to that individual. Comparative measures of cognitive competence are important in a wide range of settings, from psychometric testing of individuals in recruitment, in assessing the impact of disease or disability status, the influence of pharmaceuticals on that status, to categorisation of performance characteristics by age, genetic background, educational attainment.

**Eyeblinks** provide a way of monitoring internal brain events. The startle reflex blink, voluntary blinks and the onset of slow and deep blinks with fatigue and sleepiness are three distinct kinds of blink. When a distraction changes our attention, we tend to blink as we change attention. We also blink in order to keep our eyes moist, so that a baseline blink rate is expected to satisfy that requirement. Higher blink rates are measured during challenging visual tasks. Generally, blinks have been considered to occur fairly randomly and experimental settings therefore have focussed upon measuring average blink rates across different types of task (NASA report, 2001). Recently Seeingmachines.com have devised external stereocamera monitoring of blink rates and depth as a measure of fatigue while driving in simulated tasks.

Blinks may be voluntarily initiated and also suppressed voluntarily. It has been noted that demanding tasks including attending to videogames for period of 10 seconds or more, often lead to blinks being temporally suppressed during the task, after which immediately follows a flurry of (say) 3-5 blinks upon the 'release' of attention.

Non-randomness in blinking has been noticed in cognitively rich settings, such as in reading and conversation, but I am unaware of any measurements or theory which sets out to systematise blinks as an indicator of cognitive competence. Physically or externally induced (e.g. startle) blinks, like voluntary blinks, may be differentiated from so-called endogenous blinks (Stern, Walrath & Goldstein, Psychophysiology, 21,1984, 22-33), which reflect internal brain processing more than any specific external event.

Psychometric measurements typically control for blinking. Settings which typically incorporate blink activity include electroencephalography (EEG) where considerable effort has been directed at systematic removal of eyeblink activity from EEG traces (e.g. Bell & Sejnowski, 1995; ICA analysis, Jung, et al & Sejnowski, Psychophysiology 37, 2000, 163-178) as eyeblinks and their associated EOG signals are regarded as artefacts which interfere with EEG frequency domain measurements. As EOG signals influence the EEG activity in the human forebrain, where conscious activity associated with planning and analysis is considered to be located, it has been said that the EOG signal hinders EEG analysis of specifically higher cognitive activity.

## Section 2. Definition of the Blink Measurement Domain

The present invention is a combination of a device and a method for measuring, characterising and categorising human eyeblink activity in a wide range of experimental and natural settings. It is designed to encompass measurements from 0.5 sec (the attentional reaction time) to at least 20 seconds (variable  $T$ ) from task onset, during which attention is maintained upon a certain task. The way longer tasks are broken down into coherent sequences of this order of duration then provides a way of characterising higher brain function for an individual.

The device incorporates external sensors of muscular activity associated with the eyes, of the kind which is otherwise picked up in EEG, including electro-oculargraphy (EOG). It provides for the use of one or more electromagnetic, piezo-electric or other such sensor of dynamic eye activity, including particularly eyeblink activity. Direct measurements from contact with the head of the individual may be supplemented with indirect measures of blink activity (e.g. Seeing Machines stereovision of blinks in video traces). The blink activity, rather than being regarded as an artefact which occurs randomly across a certain interval, is temporally characterised in novel ways to characterise (a) each blink, and (b) the relationship of blinks to one another.

Within a certain task setting, blinks are classified by two primary types of measurement. Both these may be taken from the one sensor, or extracted from the signals from two or more sensors. The first is the blink depth and duration of the blink itself  $\tau$ . The second is the interblink interval,  $t$ .

The measurement of the interblink interval is essential for any local analysis of short-range coherence in blink activity, including the autocorrelation measures of adjacent blinks or other larger local blink autocorrelation clusters.

The interblink interval, itself and through higher order statistical measures such as autocorrelation in interblink intervals across a series of blinks (or for a certain duration), and preferably in this invention through cross-correlation measures between interblink interval ( $t$ ) and blink type or depth ( $\tau$ ) is claimed to hold the key to detecting and discriminating internal (endogenous) coherent brain activity without the need for, and therefore specifically in the absence of, voluntary reporting from the experimental subject, which can confound the processing metrics. These measures therefore provide independent measures of coherent brain activity

specifically oriented towards intrinsic cognitive activity, which measures may be tested for correlation with other voluntarily reported measures, such as the results of psychological, psychometric or 'intelligence' tests. Therefore these measures complement measures derived from verbal report, and also serve to discriminate the time of actual endogenous coherent brain activity from the (systematically) subsequent time – and subjective nature – of voluntary reporting of that activity.

An individual blink itself may be characterised by measures relating to the depth of closure of the eyelid (for example, the 'perclos' measure in fatigue, measuring the percentage closure of the eyeblink event). Alternatively, rather than the depth domain of a blink, the duration domain of a blink may be preferred, using such measures as the half-width in time for a blink at half its closure depth. This latter measure, which I have not seen in the literature for blinks, will be denoted  $\tau_{1/2}$ , or more simply,  $\tau$ . [Note: The half-width at half-height is a conventional measure of the strength of a spectral line in the spectrometry of light.]

### Section 3. Clustering Methods of Blink Analysis

#### Method Zero: Base analysis

Simple count of the number of blinks in the interval  $T$ , providing a mean interblink duration for the interval. The average blink rate is the inverse of this latter quantity. Similarly a mean blink depth for the interval is also determined.

#### Method One: Primary analysis

For each interval  $T$  in the experimental setting, a series of blinks is measured and characterised by a set of measurement pairs  $\{t_i, \tau_i\}$ .

When this set of measurements characterising the interval  $T$  is plotted out (for example with  $t$  the horizontal axis and  $\tau$  the vertical; see Figure 1), individual lead-interval and blink duration data pairs will be found to cluster on the  $0-t_{\max}, 0-\tau_{\max}$  map, depending upon the task setting of the interval  $T$ . Any one of a linear, a logarithmic scale, a z-scored or some other scale may be employed for each of the axes of this map for display or discrimination purposes. The range of each axis may be set empirically relative to that set or else set according to normative measures for the chosen control group.

The primary parsing of the observed clusters is into four zones:

1. Alert zone:  $t_{\text{low}}, \tau_{\text{high}}$
2. Cognitive zone:  $t_{\text{low}}, \tau_{\text{low}}$
3. Skill zone:  $t_{\text{high}}, \tau_{\text{low}}$
4. Fatigue zone:  $t_{\text{high}}, \tau_{\text{high}}$

Successive intervals  $T$  within a single session involving an initially novel task will be characterised by progression through blinking metrics characteristic of each of these



four zones in turn, in order to demonstrate the learning effect in cognition as novel tasks become more familiar.

### **Method Two: Autocorrelation and cross-correlation analysis**

Second order analysis of the blink pair data involves new plots of the  $\{t_i, \tau_i\}$  space. This involves plots of quantities derived from multiplication of adjacent members of each series together, e.g.  $\tau_i, \tau_{i+1}$ , against the intervening interval  $t_{i+1}$ . Similarly, autocorrelation in the interval space may be examined from plots of quantities derived from multiplication of adjacent members of the interval series together, e.g.  $t_i, t_{i+1}$ , against the intervening blink duration  $\tau_i$ . Finally, local cross correlation between individual  $t_i, \tau_i$  pairs are analysed by task segment.

### **Higher correlation methods:**

Other higher order correlation and cross correlation measures may be employed for display and discrimination purposes.

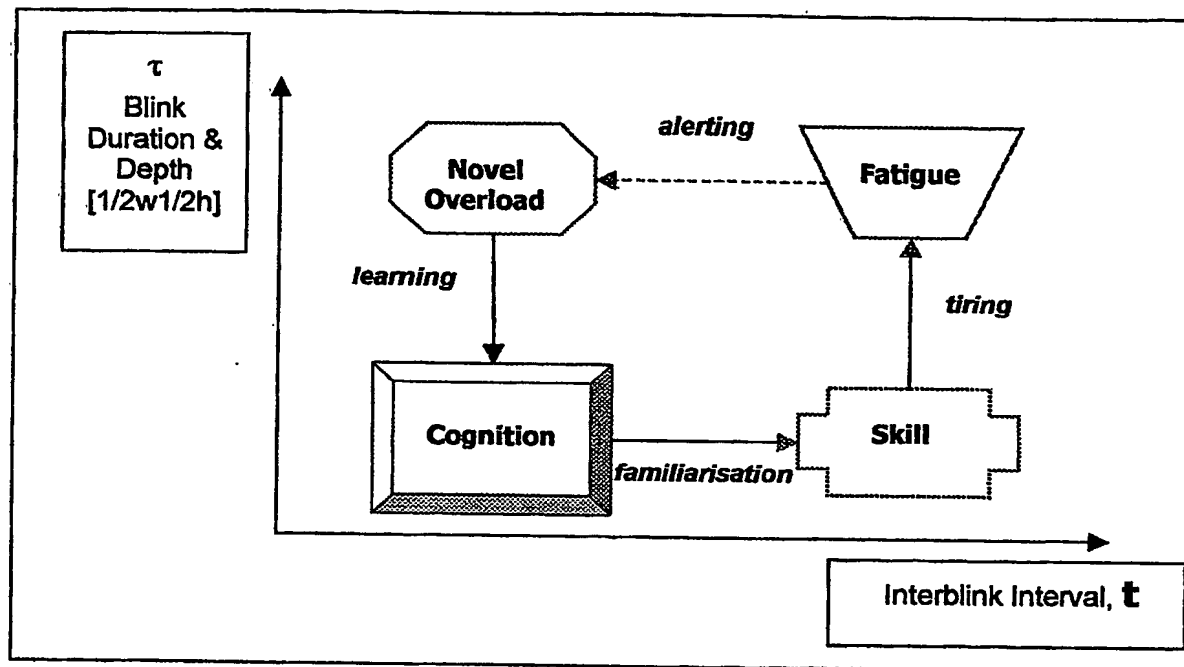
### **Seriation Methods of Analysis**

Tracking blink sequence characteristics by analysis of the arc traced out by the line joining adjacent interval, blink pairs  $t_i, \tau_i$  provides for a trajectory analysis of the blinks in the interval T. The scatter or else clustering of these traces serve to diagnose coherent behaviour strings which will broadly classify into the four zones [Alert, Cognitive, Skill, Fatigue]. Clusters observed in these traces may be numerically classified for objective comparison across tasks and between individuals on the same task.

## **Section 4. Framework for Blink Analysis into Status Domains**

### **Blinks as delimiters of object processing**

Just as punctuation parses text into coherent substructure in language expression, so blinks parse the brain's processing of its internal objects into coherent intervals. Eyeblinks have a clear association with gating events when attention switches (Burton, Psychobiology 1990 119-194), but lesser blinks (miniblinks) are cognitively rich within coherent processing sequences, acting to mark internal processing substructure associated with template processing. Blinks assessed as average blink rates (frequency measure) wash out this richness, which lies essentially in the  $\{t, \tau\}$  domain formed by (i) *interblink interval,  $t$*  and (ii) *blink duration and depth,  $\tau$* . Blink closure has been recognised as a measure of fatigue, but otherwise blinks have received little attention for the want of any theoretical perspective to drive their study as non-random markers of brain activity. This non-randomness is measurable in terms of **clustering** of sequences of blink types into four quadrants of major subtypes, as shown in Figure 1.

Figure 1. **Schematic of Blink Psychometric Clusters** - © Peter Burton 2002

Some of the richness to be explored in the blink domain is described in the textbox following. We note that almost universally, psychometric research has tightly controlled for eyeblink (in order to exclude it as an artifact), whereas I propose trans-blink temporal structure (autocorrelation) as the key to understanding coherent intervals of cognitive processing, particularly in the Type II templates characteristic of forebrain processing.

## Section 5. Blink and Task Classification Scheme

### Exhibit 1. **Blink Types**

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Reflex Blinks

Voluntary Blinks

Endogenous Eyeblinks

<b>Blink Duration</b> (40-200ms)	<i>Short/Small</i> endogenous	<i>Medium</i> startle	<i>Large/Long</i> voluntary
<b>Blink Amplitude</b>	endogenous	voluntary	startle

#### **Interblink Intervals**

Non-randomness of Blinks in Reading or Conversation

#### **Autocorrelation**

Interblink interval autocorrelative clustering as cognitive measure

#### **Episodes**

##### **Attention**

Redirect Gaze

##### **Coherent Subunits**

Skill execution

Memory capture (noise reduction/biological economy in storage)

'Chunking'

Gating

##### **Cognitive Coherence**

Mini-Blinks within STM templates

##### **Content Capture** (perceptual sub-processing)

Saccades &amp; Fixation

Jitter

#### **Performance**

##### **Fatigue**

Perclose (% of time pupil 80% covered)

Slow blink rate, long blinks

##### **On task**

Short blinks, long interblink interval

##### **Surprise**

Short blinks, high blink rate

#### **CLAIM**

*Inter-blink interval autocorrelation clustering provides realtime on-task measure of mental activity and tracking of mental processing, including cognitive accommodation of novel information, task familiarisation, and skill attainment*

#### **USE**

*Human factor exception management**HOTS index to discriminate performance (or learning) characteristics**(i) between tasks**(ii) between states of performer, and**(iii) between performers*

#### **Consumer product Application**

seeingmachines.com software for fatigue/overload while driving(autos)

#### **Medical Applications**

Cognitive impact of sleep disruption in apnea

Tracking drug &amp; treatment efficacy &amp; impact in psychological and psychiatric illness

Characterising training readiness and response in high-demand mental performance

## Section 6. Stereo-location of Axes of Blink control Mechanisms

### Three Control Mechanisms

To validate the independence of the of the three layers of brain processing which we have invoked, there needs to be specified for each an independent control *mechanism* by which processing within that 'layer' may be controlled. Two of these, I propose, are hard-wired into the evolutionary design of the brain, and reflect key aspects of the brain's topological structure. The last, a more adaptive control mechanism, has evolved with language as a specialised means of brain sub-processing.

The first, proposed for Layer 1, derived from the catecholaminergic neurotransmitters, involves *dopamine* (rising in the brainstem's *Substantia Nigra*) which gates the motor system through the midbrain and *noradrenaline* (norepinephrine, rising in the brainstem's *Locus Coeruleus*) which globally gates the attentional system through its transcortical inhibition capacity. These gating events 'clear the slate' ready for the next (inherently unpredictable) episode of processing. Memory formation occurs when recent activation is re-activated in a further episode. The more gating events occur, the more fine-grained processing becomes. Blinking while watching this screen, only to have some of its contents reactivate after the blink, serves to capture and familiarise those contents, in similar manner to the way vocal rehearsal familiarises 'lines'.

The second, which I will associate with Layer 3, is the (learned) interleaving of attention to perception in the left (LH) or the right hemisphere (RH), across the *Corpus Callosum*. This structured alternation becomes more readily available in bipedal mammals, where the serial alternation of walking provides the template for (primarily frontal) alternation of attention. I imagine stereoscopic vision to be capable of crystallising foreground of a scene in one hemisphere, and background the other, during fast alternation of depth focus. I generalise this notion to the mental capacity to 'focus' on the context (the frame; c.f. background) of an object differentially in one hemisphere, while quickly being able to switch to 'focus' on the (externally) objective contents of the internal template object in the other (the object, c.f. foreground).

*This notion, of a differentiated but mutually (and quickly) accessible switch of attention from one aspect of the internal (implicitly defined) object to another, is the essential solution to the differentiation of awareness from being alert or from being conscious. Ultimately, (through repetitive engagement with the external world) this same differentiation provides for the emergence of a self as the agent within the brain capable of 'watching' its own actions, as the 'cause' and the 'effect' attributes of an object become independently objectified.*

This interchange and differentiation becomes the template for holding internal representations of 'two-ness' which underpin all decision-making, and is the high (fast, parallel) adaptation in symbol substitution in choice-making, learned foundationally as serial choice-making.

The third mechanism, specifically available as a result of language acquisition, comes about because of the focal linguistic denotation of (internal) objects, initially as simple unitary beliefs and later as differentiated (typically invariant) and so abstracted object representations of (typically) external objects in the world. The linguistic symbols of Layer 2 processing come armed with input and output pointers (i.e. a["A"] and u[A] as above) which can become virtual (as in silent speech), where actual utterance is suppressed but can

nevertheless be 'heard' and tracked. Layer 2 control then is exhibited as motor inhibition (a relatively slow process involving neurophysiological movement units in the periphery) in favour of faster symbol-to-symbol concatenation (as in day-dreaming). Reciprocal cortico-thalamic fibres from Wernicke's area in the temporal lobe (holding indexable audition symbols a["A"]) coupled with similarly reciprocal cortico-thalamic fibres from Broca's frontal area (holding indexable utterance primitives u[A]) complete the internal shortcut circuit of mental processing. *Indexable* pointers are activated either specifically, or by way of more general local activation in search (phonetic analogy). I note that both areas are typically LH in righthanders, signifying the handling of objects as the basis of differentiating (external) object from its context (hand manipulating it).

If it can be accepted that, as I contend, these three mechanisms afford independent control of three conceptual 'layers' of brain processing, we can probably also agree that Layer 1 (first mechanism) comprises an outer loop of behavioural object processing. Within it, Layer 2 provides an inner loop of shortcut mental processing (third mechanism) which depends upon organised symbolic reference systems (vocal language, generalised to other focal perceptual-action bases to sign language or externalised to written language). Finally, within the typical (strictly?) serial processing of Layer 2, given the availability of the mirrored *sequence* templates of frontal STM, the pseudo-'parallel' process of creative symbol substitution (second mechanism) opens performance to invention.

### **Association of blink types with three underlying brain control mechanisms**

Three blink control mechanisms provide the basis for broad characterisation of blink types when these are regarded as the *punctuation marks* of internal brain processing:

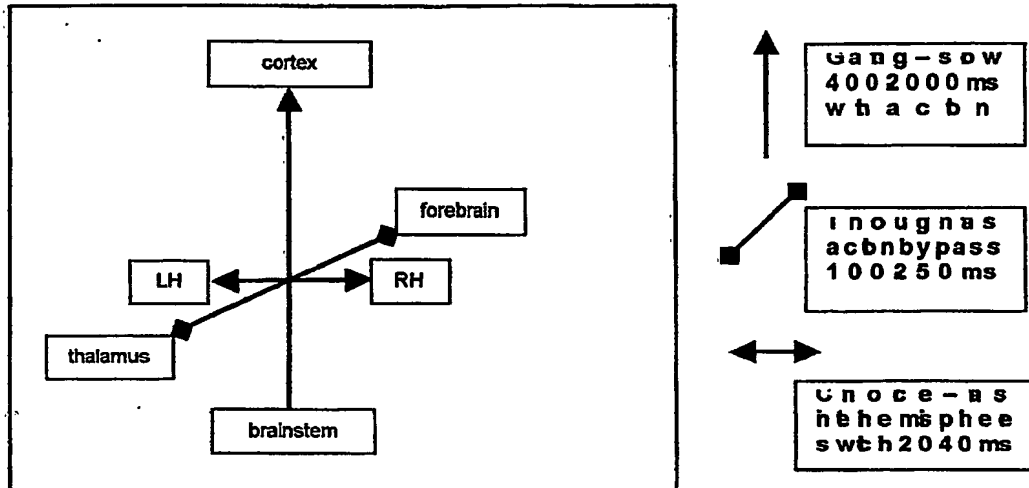
**Layer 1. Transverse control (gating):** Major blinks, typically intervening while being distracted from one task to another are associated with the underlying brain gating mechanism. These major blinks thus delimit intervals called *sessions* of reasonably focussed and coherent activity. We can liken a session to a *paragraph* of written text, in which an idea is composed from smaller components (analogous with individual text sentences, themselves comprising substructure). Major blinks are associated with endogenous catecholaminergic gating events, which operate from the higher brainstem through the midbrain, forward to the frontal lobes and tangentially across the motor, association and sensory cortex areas. This major gating signal acts to zero out current perceptual input, ready for the next session. This underlying activity for major blinks is phasic from the brainstem to the forebrain and then back across the cortical plane.

**Layer 2. Core-Cortex control (search):** Minor blinks, acting to define substructure within a coherent brain processing session, are typically associated with mental search activity. These blinks are characterised by their association with coherent cycles of reciprocal thalamo-cortical neural traffic between the midbrain and specific (language-related) areas of the cortex. Thus the minor blink activity is phasic between the midbrain and cortex, and is characterised by some measure of general action inhibition. Mental activity is focussed upon an internal (mental world) search, rather than the real world sensorimotor search of the external world, as in basic behaviour (play).

**Layer 3. Lateral control (STM & choices):** Mini-blinks are blinks largely suppressed punctuations of processing within a short burst of coherent activity. These are associated with sequence structure of dynamic processing of short-term memory processes in the frontal (and pre-frontal) cortices. Mini-blinks are thus associated with phasic brain activity which operates short-term between opposing hemispheres of the forebrain.

### Three Control Mechanisms Define the Blink Sub-Cluster Units

Figure 2. **Schematic of Blink Psychometric Units** - © Peter Burton 2003



Parsing of behaviour sequences into clusters (Figure 1) composed of articulated sequences of these units (Figure 2) provides the experimental basis of monitoring internal brain processing through blink tracking.

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